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REPORT OF THE DYESTUFFS EXPLORATORY COMMITTEE

(Council of Scientific & Industrial Research, Govt. of India)

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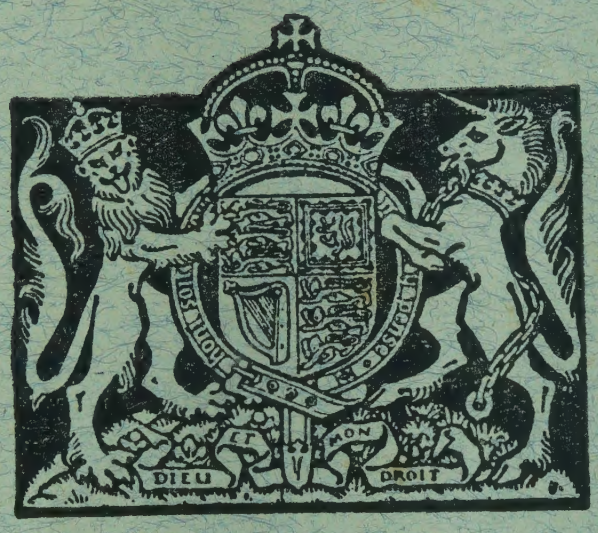
Council of Scientific and Industrial Research



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An Exploratory Committee to consider ways and means for the manufacture of synthetic dyes was set up by the Government of India on the recommendation of the Board of Scientific and Industrial Research, with the following personnel :

Sir Ardeshir Dalal (*Chairman*), Director, Messrs. Tata Sons Ltd., Bombay House, 24, Bruce Street, Bombay.

Dr. Sir J. C. Ghosh, D.Sc., F.N.I., Director, Indian Institute of Science, Bangalore.

Dr. K. Venkataraman, D.Sc., F.R.I.C., A.M.I.Chem.E., Director, Department of Chemical Technology, University of Bombay, Bombay 19.

Professor B. B. Dey, D.Sc. (London), F.R.I.C., I.E.S., Professor of Chemistry, Presidency College, Madras.

On the 29th March 1941, Mr. S. Fuchsmann of the Imperial Chemical Industries (India) Ltd., and Mr. H. S. Pink of the Imperial Chemical Industries, were added to the Committee.

The terms of reference of the Committee are as follows :

(i) To make a rough survey of the consumption of the various kinds of dyes in India ;

(ii) To survey the raw materials and heavy chemicals available for the manufacture of dyestuffs in India ; and

(iii) To consider the practicability, both technical and economic, for the manufacture of such dyes in India as are capable of production within a period of fifteen years.

At the suggestion of the Board of Scientific and Industrial Research, the Vegetable Dyestuffs Committee was incorporated in the Synthetic Dyestuffs Committee and the latter was reconstituted as follows for the year ending 31st March 1942 :—

Sir Ardeshir Dalal (*Chairman*).
Dr. S. Krishna.
Dr. K. Venkataraman.
Dr. Sir J. C. Ghosh.
Dr. B. B. Dey.

Mr. Pink left India in July 1941, and Mr. Fuchsmann died in December 1941. The Committee places on record its appreciation of the very valuable assistance rendered by Mr. Pink to its deliberations, not only during his tenure as a member of the Committee, but since. Mr. Fuchsmann, whose death the Committee deplores, also supplied very useful information to the Committee and was of great help in its deliberations.

The Committee was reconstituted by the Governing Body of the Council of Scientific and Industrial Research in January 1944, with the following personnel :

1. Sir Ardeshir Dalal (*Chairman*).
2. Dr. Sir J. C. Ghosh.
3. Dr. K. Venkataraman.
4. Dr. B. B. Dey.
5. Director of Scientific and Industrial Research (Ex-officio).

On the appointment of Sir Ardeshir Dalal as member of the Viceregal Council, Dr. John Matthai was appointed Chairman in his place.

Besides exploring the possibilities of establishing a Synthetic Dyestuffs Industry in India, the Committee has also concerned itself with individual problems of research in synthetic as well as vegetable dyes, referred to it from time to time by the Board of Scientific and Industrial Research.

In furtherance of the main object of the Committee, special investigations on the availability of raw materials were conducted by Mr. M. U. Pai and Dr. K. Venkataraman, who submitted a detailed report to the Board on the 27th June 1942. An addendum to the report was submitted in October 1942.

An analysis of the coal-tar materials available in India was made by Dr. M. R. Mandlekar, Mr. V. K. Dikshit and Mr. G. K. Marathe in the Department of Chemical Technology, University of Bombay.

Investigations are being conducted on the quantities of parent dyestuffs in commercial dyes as sold in India.

The Committee desires to place on record the deep debt of gratitude it owes to Sir Ardeshir Dalal for the very valuable services rendered by him as Chairman of the Committee since its inception. In planning our work, in collecting and examining the material required for it, in assessing the possibilities and implications of a dyestuff industry in the industrial economy of the country, and in determining the main lines of our recommendations, his knowledge and experience have been of the greatest assistance to us.

The work of the Committee has been conducted throughout without the assistance of any Secretary, Clerk or Stenographer. This has consequently thrown an additional burden of work on some of us. We take this opportunity of expressing our grateful appreciation of the labours of one of our colleagues, Dr. K. Venkataraman, who has unstintingly given of his time and effort to the work of the Committee, particularly in its technical aspects.

HISTORY OF THE DYESTUFF INDUSTRY

Before taking up the consideration of our terms of reference, we deem it necessary to deal briefly with the history* of the dyestuff industry, particularly in the United Kingdom, as well as with the question of the importance of a dye industry in the economy of a country. The history of the origin

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* The following publications may be consulted for fuller details :—
Rowe, *J. Soc. Dyers Col.*, 1938, **54**, 551.
Rowe, " Development of the Chemistry of Commercial Synthetic Dyes."
J. Morton, " History of the Development of Fast Dyeing and Dyes."
G. T. Morgon and D. D. Pratt, " The Rise and Development of the British Chemical Industry."
Reports of the Dyestuffs Industry Development Committee of the Board of Trade, 1930 and 1932.

and development of the coal-tar colour industry is of general interest, since it shows how in England, the country of its birth, the industry languished until recently, while it flourished in Germany, enabling her practically to control the world markets in its own and allied fields through skilful organisation and close attention to research.

The British can claim to have been the pioneers in the manufacture of synthetic dyes. The industry was founded in 1856, but it was necessarily preceded by the parent industries of coal-gas and by-product coking, which were started in or about 1812. To-day there are in Great Britain, besides the gas and coke industries treating and recovering the tar fractions, a number of distillers who carry out this work after collecting tar from small gas companies.

Following close upon his discovery of Mauveine in 1856, Perkin foresaw great possibilities for aniline dyes, and established a dye factory at Greenford Green, near London. The demand for aniline purple expanded at such a rate that the Greenford factory was unable to cope with it. French chemists evolved a method for the large-scale production of Magenta, discovered in 1858 by Natanson, and the nucleus of the dyestuff industry was established in France. The Perkins then patented an improvement in the manufacture of Magenta and commenced its production in England. Read Holliday of Huddersfield began in 1860 to manufacture Magenta, nitrobenzene, aniline and toluidine. Roberts Dale & Co. of Manchester made aniline dyes in the same year, followed by the firm of Dan Dawson.

In Germany the Badische Anilin und Soda Fabrik erected a dye-works at Ludwigschafen in 1863, founding the great German dyestuff industry, which was to play a notable part in the economic and industrial life of Europe.

The second stage of the dyestuff industry began in 1868 with the synthesis of alizarine by Graebe and Liebermann, and the race between England and Germany for priority in the development of alizarine and analogous dyes began. In 1864 Ivan Levinstein at Manchester commenced the manufacture of aniline dyes, including azo dyes such as Manchester Brown and Chrysoidine. German chemists were employed in English factories, but they did not find the English atmosphere congenial, and returned to Germany. It is from this period that the German dyestuff industry began to make rapid progress, outstripping England and France, although British and French chemists and manufacturers continued to make occasional advances. The decline of the British dyestuff industry during this period has been stated to be due to many reasons, which are not without significance to the project for establishing an Indian colour industry. Among the major reasons may be mentioned the unsatisfactory patent laws which enabled the Germans to take out British patents without any intention of exploiting them ; free trade in England in contrast to the high tariff walls raised by Germany ; the active encouragement in Germany of research in organic chemistry with special reference to the chemistry of the colouring matters ; the heavy excise duty on alcohol and the regulations which circumscribed its use in England ; and the superior selling organisation of the Germans.

There was, however, some progress on the part of a few firms. Read Holliday and Sons produced the first Ingrain colour, Para Red, in 1880. Levinsteins enlarged the scope of their work with specialisation in naphthalene derivatives. The founder of the firm, Ivan Levinstein, worked incessantly for the amendment of the British patent laws with a view to secure better

protection for the British colour firms. He thus antagonised the large German firms, who stopped supplies of intermediates, but his tenacity and perseverance ultimately triumphed and the Patent Laws Amendment Act was passed in 1907, which included a clause to enforce compulsory working by foreign patentees of their British patents. One important result of this enactment was the establishment by the German firm of Meister, Lucius and Bruning of a factory at Ellesmere Port for the manufacture of synthetic indigo, which proved to be a very useful asset during the Great War.

Following the discovery by Bohn in 1901 of Indanthrene Blue, the Germans started manufacturing a long series of very fast dyes from anthraquinone. The competition was too severe for the British industry, but a few factories in Great Britain held on, among whom were Read Holliday and Sons, Levinsteins, Claus and Ree, Williams, the British Alizarine Company, and the Clayton Aniline Company.

In 1904 Sir James Morton introduced to the cloth trade an innovation which seemed revolutionary at the time by marketing fabrics with guaranteed fastness against fading. For this purpose Morton Sundour Fabrics, Ltd., had to import most of their colours from Germany. Immediately prior to the outbreak of war in 1914, Britain was the greatest textile producing country in the world with the largest export trade, the peak year being 1913, and yet she had no self-contained dye-making industry. Over eighty per cent. of the dyes consumed in Great Britain were actually imported from Germany and Switzerland, and even the balance of twenty per cent. representing indigenous production was based for the most part on German intermediates.

The world shortage of dyes during the war of 1914-18 brought home to many countries the risks inherent in dependence upon external sources for the supply of dyes essential to their textile and other trades, while it also came to be recognised that there were serious dangers in the neglect of the organic chemical industry. The realisation of these facts after the outbreak of the war induced the British Government to assist in the establishment of a sound dyestuff industry in the United Kingdom. In 1915 the Government, mainly through the efforts of Lord Moulton, took over Read Holliday and Sons, found money for its development and changed its name to British Dyes Ltd. New and extensive factories and laboratories were built. Under the impetus given by the dye shortage, but independently of Government help, other British firms also made progress. The manufacture of anthraquinonoid vat dyes, not previously produced in England, was established by the initiative of two firms, Levinsteins and Morton Sundour Fabrics Company, subsequently known as Scottish Dyes Ltd. Extensions were undertaken by the British Alizarine Company and Clayton Aniline Company. An independent offshoot of Read Holliday and Sons, L. B. Holliday & Co., came into existence during the war, and many other similar smaller organisations also extended their sphere of activities.

In 1919, at the instance of the Government, a new corporation (The British Dyestuffs Corporation) was promoted by the merger of British Dyes Limited and Levinsteins Ltd., with an authorised capital of £10,000,000, the Government subscribing ten per cent. of the share capital. Large research laboratories were set up and millions of pounds were spent in the rapid development of every branch of the industry, with special reference to research. The import of foreign dyes was prohibited by an Order in Council. Following a legal decision by Lord Sankey, however, the Board of Trade was unable to enforce the order. Dyes and intermediates continued to be

imported in large quantities and coupled with the trade depression, the prosperity of the industry was seriously threatened. Research staff was again cut down and trained men on the production side were also discharged.

The Dyestuff Importation Act of 1920, which forbade the entry of dyes and intermediates into Great Britain, except such dyes as could not be produced in the country at a reasonable price, was then passed to save the situation. The industry was thus promised a sheltered position during the period of its renaissance.

The Imperial Chemical Industries was formed in 1926 by the fusion of Brunner, Mond & Co., the Nobel Industries, United Alkali Ltd., the British Dyestuffs Corporation, Scottish Dyes, and Oliver Wilkins & Co. The British Alizarine Company was added in 1932. Imperial Chemical Industries has a total capital of over sixty million pounds, and in the manufacture of heavy chemicals and dyes it has a virtual monopoly which has contributed to its very influential position in the British Empire in recent years. In the hands of this Corporation and the few remaining independent firms, the British production of dyestuffs now amounts to over ninety per cent. of the requirements of their home market. The Dyestuff Import Regulation Act was given a second lease of life in 1940, although the industry had already made tremendous progress under the stimulus of the Act. The Act is still in force. An outstanding achievement of the British dyestuff industry was the development of the manufacture of a series of anthraquinonoid vat dyes, solubilised vats, and dyes for acetate silk. Not a single pound of the anthraquinonoid vat dyes was made in England in 1913 and today the production is over five thousand tons.

Important developments took place simultaneously in other countries. It was soon realised that the individual companies concerned with the manufacture of dyes and chemicals could not stand the ever-increasing competition. Germany was the first to take the lead in this direction, even prior to England. In 1925 the German dyestuff industry, in order to gain its former position, formed the Interessen Gemeinschaft für Farbenindustrie A.—G. (briefly known as the I.G.) by amalgamating six of the largest dye producing concerns. It represented sixty-two per cent. of the total capital of the German chemical industry (more than 1,000 million marks) and was affiliated with about a hundred manufacturing companies.

In the United States the Schollkopf Aniline and Chemical Company of Buffalo was the largest producer before 1914. New factories were then started by the National Aniline Company of New York (a component firm of Allied Chemical Company), now the largest producers in the United States, and Du Pont de Nemours & Co. of Wilmington, Delaware. In 1918 the President issued orders prohibiting the import of dyestuffs from specified countries, and steps were taken in due course to amalgamate the smaller concerns into larger corporations.

In France similar consolidations have occurred. The Societe' Anonyme des Matieres Colorantes de St. Denis and the Compagnie Nationale des Matieres Colorantes were promoted during the war by the French Government. These and other smaller concerns were later amalgamated into one large chemical combine, Etablisements Kuhlmann. France, moreover, levied high import duties on foreign dyes. The French industry was integrated and acted as a competitive unit.

Production of synthetic dyestuffs on an industrial scale was initiated in Japan in or about 1914. Since then the industry as a whole has made

general progress, fostered by protective measures on the part of the Government, such as subsidies and an import licence system. However, in spite of the progress achieved, the Japanese dye industry is generally conducted on a small scale in comparison with Great Britain, Germany and the United States.

Germany, the United States of America, Russia, Great Britain, Japan, Italy, France, Switzerland and Poland were the main dye manufacturing countries in 1936. Except in the case of Germany and Switzerland, the industry in each country concentrated largely upon production for the domestic market. Germany was reported to be exporting about fifty per cent. of the production, while Switzerland exported as much as ninety-five per cent. Germany is known to be the world's leading producer of synthetic dyes, and the United States the second. Official figures are lacking in the case of Russia, but she is believed to have attained the third place.

There is no dyestuff firm in Germany of any importance, apart from the I.G. The Swiss dyestuff manufacturers are co-ordinated, but not amalgamated ; for all competitive purposes, they act together as a unit. In France the industry is similarly organised. In Russia it is State-controlled. In the U.S.A. there are a few large corporations controlling the industry, and in Japan also three large firms control the major part of the industry. In 1931 the Imperial Chemical Industries concluded a commercial agreement in regard to dyestuffs with a group of continental manufacturers, which included the I.G., Sandoz, Geigy, Ciba and the French Kuhlmann group. They have also an agreement with Du Pont in the U.S.A.

It is obvious from this account of the development of the dyestuff industry that it is essentially of an international character, and that no country is capable of standing on its own feet with regard to all its products. Even Germany found it necessary to conclude agreements with other large producers of dyes in the world. Another lesson that emerges from the record of the industry is that it is not one which can be developed successfully by comparatively small individual firms, but that amalgamation and organisation on a nation-wide basis are essential for success. A further requirement is extensive and continual research.

THE VALUE AND IMPORTANCE OF THE DYESTUFF INDUSTRY IN THE ECONOMY OF A COUNTRY

Professor A. G. Green, speaking before the British Association at Glasgow in 1901 said : " The coal-tar colour manufacture has well been called the flower of the chemical industry. Although in absolute money value of its products not equalling some other branches of industrial chemistry, it represents the highest development of applied chemical research and chemical engineering, and may well be taken to be the pulse of the whole chemical trade. Indeed, a country which allows the most scientific branch of chemical industry to languish cannot expect to maintain pre-eminence for long in any simpler branch of chemical manufacture." These remarks made in 1901 apply with even greater force today.

The dyestuff industry acts as an important link in the chain of other essential chemical industries, such as the heavy chemical inorganic industry and coal-tar industry on the one hand, and the fine chemical and pharmaceutical industry, explosives, synthetic plastics and solvent industries on the other.

Describing the reactions of the textile trade in Great Britain and the country as a whole to the acute and serious position created by the shortage of dyestuffs and allied chemicals during the last war, Bruce* says : " The war of 1914 was a surprise to civilisation. In this country there had long been held tenaciously the attitude that international trade made all nations interdependent and that it was best for individuals to buy from the particular source and country, cut out, or so positioned, to supply the commodity required which was thought to be the cheapest and best. This attitude was right or wrong. The facts proved merely that for this country it was wrong under the circumstances for the period mentioned. We alone among the great industrial nations held this view and had practised what we preached. In this attitude, even if ethically correct, we overlooked the fact that what may be true for basic raw products definitely does not apply where many high technical manufactures become and are essentially raw materials for national industries, and on which manufactures in any emergency might be so dependent that without them neither the industries nor indeed the country could exist for long. It surely is apparent now that any nation, which, for the maintenance of its population, has to keep its position as an industrial power, must, for its continued existence, maintain and control supply and be self-sufficient for every vital manufacture at whatever cost . . . It is most significant that even in countries like Great Britain and the United States, twenty-five years have not been sufficient time to make up all the leeway that had been lost in the years that the locusts had eaten. In the opinion of those that have studied the position, it seemed doubtful whether the leeway could ever be made up, because the industry is no longer merely the dyestuff industry. It has broadened and extended the basis of activity on which it started to an almost bewildering extent . . . What had been known and referred to as the dyestuff industry had, in fact, become basically and fundamentally, the infinitely greater synthetic organic chemical industry. In addition, undertakings based on highly developed pressure and catalytic syntheses are of greater significance than those already developed in connection with the manufacture of dyes. Arising from the dye industry as a basis, almost any organic substance can, if necessary, be made in great quantities, e.g., sugar, yeast, alcohols from waste wood, synthetic fats from water-gas, etc., in fact the only limit being the size and design of plant, availability of basic raw material, and, of course, the comparative economic considerations at the time. It is this wider aspect of the subject which must be appreciated to envisage the developments possible from dyes as a basis, for it is undoubtedly on that foundation that the enormous edifice of the synthetic chemical industry has been built." . . .

We have deemed it necessary to give these somewhat lengthy extracts from the remarks of Bruce because of their obvious applicability to the condition of India at the present day. The importance of the dyestuff industry to the economy of the country is only just being realised, and inadequately realised even today. Its value as the highest development of the chemical industry and as a basis from which almost any organic material could be manufactured, its wide ramifications and interconnection with other industries, several of them larger in size and money value than the dye industry itself, such as inorganic chemical and coal-tar industries and the explosives, fine chemicals, pharmaceuticals and synthetic plastics, is still inadequately appreciated. The textile industry is the premier industry of India, and yet on the outbreak of war it had to face an acute shortage of dyes and auxiliary chemicals.

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* *J. Soc. Dyers Col.*, 1941, **57**, 305.

The incidence of disease in India is one of the highest in the world. Malaria is the greatest scourge of the country, but with the cutting off of supplies of quinine after the entry of Japan in the war, India had to face a very serious situation because synthetic substitutes, such as Atebrin, could not be produced locally, owing to the rudimentary condition of the pharmaceutical industry. There has been progress in India, since the war, in the production of tinctures, extracts, galenicals, etc., but very little in the manufacture of synthetic chemicals.

The manufacture of explosives to the extent to which it was possible had to be hastily devised through the help mainly of the steel industry which put up plants for the distillation of benzol in connection with its coke ovens. There can be no question that the establishment of a synthetic dyestuff industry in India, if it were feasible, would be of the utmost value, not only to the textile and other industries, but also for safeguarding national health and defence.

The influence of the dye industry on other industries may be briefly reviewed. First, there is the group of industries which are closely associated with the dye industry and act as feeders to it : coal-tar distillation, the heavy chemical industry and, to a certain extent, the solvent industry. Then we have the second class of industries, which have developed from the dye industry or depend on it for some of their raw materials.

Coal-tar industry : The coal-tar industry must be regarded as of great national importance. We have a fairly well organised by-product coking industry in India working more or less in conjunction with the iron and steel industry. The coal-gas industry is also in existence, though on a small scale. We have few undertakings treating tar, and these concern themselves mainly with road tar and benzol. Very valuable fractions of tar, which could form the basis of important industrial products, are not extracted at present and go to waste.

Lately, owing to war requirements, large quantities of benzene and toluene are being produced. A well organised coal-tar industry working in co-operation with it is one of the essential requirements of the dye industry.

Inorganic heavy chemical industry : This is the most important feeder industry, and has in its turn received great stimulus from the growth of the synthetic dye industry. As pointed out in the Pai-Venkataraman Report dealing with the requirements of raw materials for a dyestuff industry in India, the inorganic heavy chemicals constitute, in tonnage, nearly ninety per cent. of the total of the raw materials required. The dyestuff manufacturer has to use in particular sulphuric, hydrochloric and nitric acids, caustic soda, soda ash, ammonia and chlorine in very large quantities.

Solvent industry : Another industry which has developed largely owing to the growth of the dye industry is the manufacture of solvents.

Pharmaceuticals and fine chemicals : The raw materials, intermediates, plant and personnel at the disposal of the dyestuff manufacturer are suitable for the manufacture of a wide variety of fine chemicals and pharmaceuticals and the dyestuff manufacturer, directly or through associated firms, is often in practice a large-scale producer of such fine chemicals. It is difficult in fact to decide where the dyestuff industry ends and the fine chemical industries begin. Of these subsidiary industries, the most important is the manufacture of synthetic medicinal chemicals.

The range of medicinal chemicals derived from coal-tar hydrocarbons and dye intermediates is too numerous to be listed, and a few common

examples must suffice, such as phenol, resorcinol, phenolphthalein, sodium salicylate, aspirin, benzoic acid, phenacetin, saccharin, sulphanilamide, sulphapyridine, sulphathiazole, salvarsan, carbarsone and other arsenicals, atebrin and plasmoquin, stilbestrol, nicotinic acid and thiamin (Vitamin B_1). There are in addition a few dyes which are themselves of value as drugs and for staining purposes in cytological and bacteriological work.

Synthetic resins : So important is the role now played by plastics that the present period is sometimes called the plastics age. The first and commonest of the synthetic resins is Bakelite, which is made by the condensation of phenol and formaldehyde, both being dyestuff intermediates. For other plastics also, some of the raw materials can be made available by the dyestuff manufacturer.

Explosives : Explosives and munitions are closely related to dye intermediates. The manufacture of explosives has been greatly improved by advances in the unit processes of organic synthesis involved in dye manufacture and the relevant plant developments. Of these the plant and processes for nitration are the most widely used in explosives manufacture. Allied to these are some of the poison gases which are manufactured from the raw materials and intermediates of the dyestuff industry with suitable modifications.

Photographic chemicals : Considerable quantities of special and highly purified dyes are used for colour photography for sensitising in the infrared and for panchromatic films. Many photographic developers are products of the dyestuff industry.

Flavours and essences : Synthetic organic products take to some extent the place of natural substitutes in the perfumery and flavouring industry. Among the coal-tar products used in perfumery may be mentioned coumarin, the first synthetic perfume ; diphenylmethane, a hydrocarbon used as a perfume of the geranin type ; aromatic ketones ; benzoic, anisic, salicylic and cinnamic acids, which in combination with aliphatic alcohols give a wide range of esters for perfumery.

SURVEY OF THE CONSUMPTION OF DYES IN INDIA

The first term of reference before the Committee is " to make a rough survey of the consumption of the various kinds of dyes in India." There are two obvious sources from which such information can be derived. One would be the import statistics, and the other the actual figures of consumption obtained from the textile industry and other consumers of dyes.

The annual statement of the Sea-borne Trade of India gives from year to year the figures of imports and the corresponding rupee values of dyes, but the hundreds of dyes which are in use are classified under thirteen heads. The statistics of the quantities of these thirteen classes of dyes imported during the years 1937-40 are given in Appendix I. The figures for the years 1940-41 and 1941-42 were supplied to the Chairman at his special request by the Director-General of Commercial Intelligence and Statistics, and the statement is to be treated as confidential. Enquiries made of the Director of Chemicals ; Secretary, Commerce Department ; Director-General of Commercial Intelligence and Statistics ; and Sir Shanti Swarup Bhatnagar indicated that no further data concerning individual dyes could be obtained from Government sources.

At the request of the Committee, the late Mr. Fuchsmann provided figures of consumption for dyes classified into eighty to hundred groups

(Appendix II), and he later also made available to the Committee the " anticipated annual sales " of the 51 dyes in our plan. It is to be emphasised that the figures do not represent the actual consumption of these dyes in any given year, but are the quantities which Mr. Fuchsmann, in the light of his knowledge of the dyestuff trade in India, including both I.G. and Imperial Chemical Industries, anticipated that the Indian dyestuff manufacturer might be able to sell in the immediate future.

We regret our inability to produce more satisfactory figures of the consumption of dyes in India in spite of all our efforts. We suggest that, for the future, the Department of Commercial Intelligence and Statistics may be requested to maintain a record of the import figures of each important individual dye, so that they may be available to intending manufacturers of dyes in India.

A PLAN FOR AN INDIAN DYESTUFF INDUSTRY

We have described at some length the history of the dyestuff industry and its importance in the national economy. It follows then that, if it is feasible, the industry should be established in India as early as possible. We have learned from the past history of the industry in Great Britain and of the lessons of the two great wars that unless a country is self-sufficient in this vital matter, its economic development is stunted in peace and liable to be seriously impaired in war. The industry is important not only because of its direct relation to textiles, the largest industry of India, but also because of its influence on the development and progress of the heavy chemical industry, the coal-tar industry, the drug industry on which the health and well-being of the masses of the people depend, and the munitions industry which is of such obvious importance in war.

The whole position regarding the availability of the necessary raw materials for the establishment of the industry has been examined in a special report submitted by Messrs. Pai and Venkataraman. The report discloses that the raw material position is sufficiently favourable to enable the industry to be started in India. In the early stages of its work, the Committee had in view a 15-year plan for the production of a limited number of dyes in great demand by the textile industry. In view of the growing desire for shades of all-round fastness, the list of 51 dyes included a high proportion of vat colours and azoic components. The series of dyes mentioned in Appendix III comprised 13 vat colours, 1 sulphurised vat colour, 3 solubilised vat colours, 4 naphthols, 8 bases and salts, 9 direct colours, 7 basic colours, 3 acid colours, 2 sulphur dyes and 1 mordant colour. Upon further consideration and discussion with experts, we have now come to the conclusion that it is possible under the conditions indicated later, to manufacture these 51 dyes in five years, and that within a period of fifteen to twenty years it is feasible to manufacture all the dyes in substantial demand in the country.

Value of the 51 *dyes* : Messrs. Imperial Chemical Industries (India) Ltd. have given us a statement of the prices of the 51 dyes in 1936 and 1938. The grand total adds up to Rs. 1,85,58,775. According to Mr. Pink, the total value of the dyes at the pre-war c. i. f. prices is £1,112,000, corresponding to Rs. 1,48,27,000. The average value of the imported dyes into India during the last three pre-war years was Rs. 3,35,66,884, so that the 51 dyes which constitute the first part of the plan would represent about 50 per cent. of our dyestuff consumption.

RAW MATERIALS FOR THE MANUFACTURE OF DYESTUFFS IN INDIA

The second term of reference before the Committee is to survey the coal-tar raw materials and the heavy chemicals produced in India and examine the extent to which they will be available for the dyestuff industry. The position of India with regard to the availability of the raw materials for the dyestuff industry is not like that of highly industrialised countries which obtain most, if not all, of their raw materials from their own chemical industries. Owing to the comparatively undeveloped state of the heavy chemical industry in India, it was found that some of the inorganic raw materials were not produced at all, while those that were produced had been mostly allocated to other industries, so that the pre-war capacity of our plants was not adequate to meet the demands of the dyestuff industry. The position has improved since the outbreak of the war, as many new plants have been erected and come into operation. As already mentioned, Mr. M. U. Pai and Dr. K. Venkataraman have conducted an investigation into the availability of the raw materials for the industry and submitted their report. Their work can be divided into two stages. The first was to estimate the total requirements of the coal-tar hydrocarbons and the inorganic chemicals required for the 51 dyes in the fifteen-year plan. The second stage was the collection of statistics of the production of the various raw materials in India. We are now in a position to make certain recommendations on the strength of the findings of the Pai-Venkataraman Report. Before recording these, however, we feel that it is desirable to review some aspects of the report on the availability of the raw materials, so that our conclusions could be appreciated in the correct perspective.

Purity of commercial dyes : The first difficulty encountered in the survey was the absence of any reliable data on the percentage purity of the individual dyes. Nearly all the commercial dyes, except perhaps those used in the pharmaceutical industry and for colouring foods, are adulterated or standdardised by the use of inorganic salts or organic diluents. In the case of a very small number of dyes, such as alizarine, the exact strength of the dyes is specified by the trade. Generally, however, they are sold on the standardised shade basis and it is often difficult, if not impossible, to judge off-hand the exact strength of these colours. In many cases the principal dye is admixed with varying proportions of other dyes to obtain the required shade. These factors affect the enquiry in two ways. In the first place, the total quantity of the parent dye or dyes cannot be accurately determined except by physical and chemical methods. Besides, the samples of dyes available in the market at the present time could not be regarded as standards. The brands marketed by the I.G. and the Imperial Chemical Industries (India) Ltd. are not necessarily of the same strength, and there are appreciable differences between the ostensibly equivalent I.G. and I.C.I. products. Research on the commercial dyes in the plan, the nature of the adulterants, the auxiliary agents that may be present, and in some cases the chemical constitution of the parent dyes, has been taken up by the Committee, but an investigation to cover the entire range of commercial dyes could not be made in the time at its disposal.

Manufacturing practice : The next difficulty encountered in the survey was the lack of accurate data regarding manufacturing practice. In the absence of practical experience which industrial chemists in this country do not possess, an allowance for these factors was therefore necessarily to be made in assessing the accuracy of the results arrived at. What is required

for our purposes, however, is not the ascertainment of the scientifically exact quantities of the raw materials for the manufacture of any particular dye, but a general idea of the total requirement of the raw materials for the purpose of manufacturing the desired series of dyes. Without claiming, therefore, very great accuracy for the figures as mentioned in Appendices IV, V and VI, it can be asserted that they give a reliable estimate of the general requirements of the raw materials for our purpose. These figures have also been submitted to an independent check. The Committee had requested Mr. Pink of the Imperial Chemical Industries to collect practical working data on the raw materials and intermediates. The figures were supplied by Mr. Pink after the main report of the Pai-Venkataraman Committee was out. Mr. Pink's report (Appendix VII) dealt generally and briefly with the different aspects of the dyestuff industry, showing its requirements of raw materials, the money value of the plan and the cost of the plants required to implement the plan. His figures were in some cases different from those contained in the Pai-Venkataraman Report. In the Pai-Venkatataman addendum to their report, the significance of these variations has been explained in detail.

In arriving at the figures in the report, allowances have been made for the recovery of excess chemicals, and the figures in Appendices IV, V and VI refer to the essential "consumables" required annually. The procedure followed has been explained in detail in the Pai-Venkataraman Report.

It is necessary to allow for a certain amount of flexibility in the matter of our requirements of raw materials. One of the most important reasons for this flexibility is the fluctuation to be expected in the demand for individual dyes. Secondly, there are bound to be many changes in the methods of manufacture of dyes and intermediates with the passage of time and progress in technology. Thus the production programme for the inorganic chemicals should not be too rigid. Taking all these factors into consideration, the Committee has arrived at the figures of the raw materials for the 51 dyes in the plan in respect of inorganic chemicals, coal-tar materials and solvents, recorded in Appendices IV, V and VI.

Production data : From a knowledge of the qualitative requirements of the plan, the inorganic chemicals were listed and classified (Appendix VIII). The list, accompanied by a questionnaire (Appendix IX), was circulated to manufacturing firms and officials of the Government and Indian States (Appendix X). In all forty-four firms and sixteen persons were addressed. Prompt replies were received in a few cases, but in general the response was poor. The production data thus obtained are tabulated in Appendix XI. For a few important heavy chemicals, the data obtained from Government and from a report submitted by a Committee of the Indian Chemical Manufacturers' Association have been tabulated in Appendix XII.

A list of coal-tar raw materials was similarly prepared (Appendix XIII) and sent together with the questionnaire (Appendix XIII) to the firms listed in Appendix XIV. The total production figures for each of the coal-tar raw materials, supplied by the tar distillers, have been tabulated in Appendix XV.

It was, however, realised that the data collected early in the war did not present a true picture. Large-scale expansion had taken place since then to cope with the military requirements. This was particularly the case with heavy chemicals. The Chairman, therefore, communicated with Sir

Shanti Swarup Bhatnagar and obtained from him the data of production prepared for the use of the Supply Development Committee. The list, which is confidential, is reproduced in Appendix XVI. A report on Indian coal tar and its products, prepared by Dr. Forrester for the use of the Basic Chemicals Sub-Committee of the Supply Development Committee, was also furnished by Sir Shanti Swarup Bhatnagar and has been reproduced in Appendix XVII, in view of its utility in planning the coal-tar distillation industry. A statement of the latest figures of the annual production of coal-tar products by Indian distilleries, supplied by Sir Shanti Swarup Bhatnagar, is reproduced in Appendix XVIII. Appendix IV is a combined list of our requirements of inorganic chemicals as finally computed, with their availability, according to the latest information at our disposal. A similar list of coal-tar raw materials is given in Appendix V.

The whole position regarding the relationship between the dyes in the Committee's Plan, the relevant intermediates and the coal tar and other raw materials is presented in a series of flow sheets as indicated below:

1. Intermediates from benzene.
2. ,, ,, phenol.
3. ,, ,, toluene.
4. ,, ,, naphthalene.
5. ,, ,, anthraquinone.
6. Raw materials (organic and inorganic) for the dyes from benzene.
7. Raw materials (organic and inorganic) for the dyes from benzene, toluene and naphthalene.
8. Raw materials (organic and inorganic) for the dyes from anthraquinone.

Review of the raw material position : Having thus obtained an approximate idea of the total raw material requirements for the 51 dyes, and of their output, present and planned, the raw material position, from the standpoint of the projected dyestuff industry, may be now examined. The present discussion deals, however, only with the major requirements, and must be read in conjunction with the Pai-Venkataraman Report.

Sulphuric acid : By far the most important raw material for the industry among inorganic chemicals is sulphuric acid, including oleum. Our requirements of this acid are about 10,000 tons every year. Both the pre-war production and consumption amounted to 60,000 tons each, being the chief basic raw material in chemical and allied industries. The present production is estimated to be about 90,000 tons and no further production can be obtained from existing plants. The new schemes that have been planned will yield about 7,100 tons. The present demands are large and amount to nearly 1,17,000 tons. After the war, therefore, there should be an adequate surplus after satisfying the normal civil demands available for newly created industries. It should not be difficult then to obtain our requirements of 10,000 tons of this acid from the surplus, although it should be realised that in case the fertiliser industry for the manufacture of ammonium sulphate and superphosphates is organised on a scale commensurate with the need for them, much larger amounts of sulphuric acid will have to be produced. On the other hand, there has been a tendency in other countries possessing no sulphur resources to develop alternative methods of preparation for chemicals otherwise dependent on sulphuric acid ; examples are nitric acid by ammonia oxidation and hydrochloric acid by the direct combination of

hydrogen and electrolytic chlorine. While it may therefore be concluded that the supply of sulphuric acid is not an obstacle to the establishment of a dyestuff industry, we recommend that the dyestuff industry should make sulphuric acid for its own requirements in order to reduce costs, eliminate freight charges, and ensure the regular and guaranteed supply of a basic raw material. In view of the inadequacy of our sulphur resources, the gypsum process should be employed.

Oleum : The position regarding oleum is at present unfavourable, but the potential source of supply is increasing rapidly. Oleum of about twenty per cent. SO_3 content is reported as being manufactured by one concern to the extent of about 350 tons a year. There are four contact plants working in India, while a fifth one is stated to be under erection. The total maximum capacity of these plants is said to be 100 tons of 100 per cent. acid per day or proportionately less of higher strength oleum. Moreover, the Department of Supply, Government of India, is planning to import four more contact plants of ten-ton capacity each, as part of their war production programme. Our total requirements of oleum are about 1,900 tons of acids varying up to 66 per cent. SO_3 and about 600 tons of monohydrate. Adequate supplies of oleum may thus be anticipated. It should be noted, however, that the greater portion of the total output, which is included in the total production of sulphuric acid mentioned already, is earmarked for many other uses. Further, the transport of oleum over long distances involves many risks and dangers, due to its corrosive nature. It is therefore recommended that the dyestuff industry should install a contact plant with ancillary equipment suitable for the production of oleum up to 80 per cent. strength.

Chlorsulphonic acid required for some of the special sulphonation processes, e.g., in the manufacture of the solubilised vat colours, is being produced in India. It is understood that the small-scale production (about five cwts. per day), undertaken at the Mysore Government factory at Belagulla in connection with the preparation of Chloramine T, has been continued, to meet the demand from the pharmaceutical industry, although Chloramine manufacture has been suspended. Since, however, the dyestuff industry is to produce its own hydrochloric acid and oleum, we recommend that it may also produce chlorsulphonic acid in accordance with its requirements.

Hydrochloric acid : The total requirements of the dyestuff industry are 1,700 tons of ordinary technical acid and 260 tons of acid free from sulphuric acid, and a little (five tons) of fuming (39 per cent.) acid. It has been estimated that a considerable amount—about 700 tons of 33 per cent. pure acid—may be recoverable in the various reactions involved in the manufacture of intermediates and dyes. Government have issued on different occasions conflicting data on the production of hydrochloric acid. According to the statistics supplied by the Supply Department, the pre-war production and consumption of hydrochloric acid (400 tons each) compare favourably with the figures in some Government publications (Appendix XII), but are in striking contrast with the figure given by Mr. Sen Gupta (1,200 tons) ("Development of the Heavy Chemical Industry in India," Bulletin of the Indian Industries Research Bureau, No. 8, New Delhi, 1937). The present production is reported to be 2,500 tons, of which 1,500 tons are stated as being essential for civil use, and 1,000 tons for defence purposes. After making an allowance for the 700 tons estimated as obtainable as a by-product in the dyestuff industry, we have to make provision for 1,260 tons (1,960—700) of the acid, a quantity higher than the 1,000 tons used for defence purposes at present. Thus, even assuming that all the hydrochloric acid

used for defence purposes may be available as surplus in peace time for the dyestuff industry, the demands of the dye industry cannot be met from the total production of Indian factories. Arrangements will, therefore, have to be made for the manufacture of the acid by synthesis from hydrogen and chlorine or by the old method ; in the latter case, the salt cake can be utilised for making sodium sulphide required by the dyestuff industry. Taking into account our later recommendation that the dyestuff industry should install the necessary plant for the production of caustic soda and chlorine, we recommend that synthetic hydrochloric acid should also be made by the dyestuff industry itself.

Nitric acid : Nitric acid is required to the extent of 4,500 tons annually. The nitric (like the hydrochloric) acid supply is one of the major problems to be faced and solved before dyestuff production can be undertaken ; it is not only the availability, but also the price that constitutes the difficulty. Unless the dyestuff manufacturer can get his supply of nitric acid at a fraction of its normal price in this country, nitration, perhaps the most important unit process in the synthesis of intermediates, cannot be undertaken economically. The prevailing method of decomposing a natural nitrate with sulphuric acid is expensive. The problem can be solved if plants for the oxidation of ammonia from the fixation of atmospheric nitrogen are installed. The matter is engaging the active attention of Government in connection with the production of synthetic fertilisers.

The total production, present and planned, of nitric acid as reported to us is 750 tons of ordinary technical quality (sp. gr. 1.4) forming sixteen per cent. of our requirement, whereas according to pre-war Government statistics it was 1,500 tons or one-third of our requirement. The figure supplied by Sir Shanti Swarup Bhatnagar is 2,750 tons. Although our nitric acid plants are capable of increased efficiency and expansion, it is doubtful if any of the present production would be available to the dye maker. In this connection, the large amounts of nitric acid produced at present by the Government munition factories have also to be taken into account. If peace-time production is to be independent of future military requirements, the dyestuff industry will have to make its own provision for the manufacture of nitric acid in order to secure a continuous, dependable and economic supply. This is a raw material which, like sulphuric acid, is of such fundamental importance to the industry that it is best for it to be independent of outside sources of supply. We recommend therefore that nitric acid by oxidation of ammonia should be manufactured by the dyestuff industry.

Caustic soda : Our estimates of requirement are about 4,000 tons. It was not being manufactured in India before the war, and the total consumption was of the order of 25,000 tons. The present requirements, under war-time conditions, are estimated to be 35,000 tons, out of which 16,000 tons are necessary for civil use and 19,000 tons for defence purposes. The largest consumers of this chemical are the soap, textile and paper industries. The peace-time demand should be estimated at about 25,000 tons, since a part of the normal civil demands for caustic soda has probably been included in the requirement for defence industries. The existing production of caustic soda and possible expansion are 3,000 tons and 8,700 tons according to the Supply Department, but according to the information received by us in reply to our questionnaire, they are 4,000 tons and 12,400 tons. The sum of the present and planned production may be taken as about 16,500 tons. It is evident that the present production is insufficient to meet even normal demands. The total production capacity will have to be more than doubled

before the dyestuff industry can be sure of an indigenous supply of caustic soda.

We recommend that caustic soda and chlorine on an adequate scale should be manufactured by the dyestuff industry by the electrolytic method.

Caustic potash : The estimate for total requirements has been reduced to 500 tons in view of Mr. Pink's data. The present production is *nil* and a comparatively small production has been planned. This alkali is essential for the manufacture of anthraquinonoid vat colours and cannot be replaced by caustic soda. It is prepared mainly from potassium chloride by the electrolytic method, as in the manufacture of caustic soda. Messrs. Tata Chemicals may undertake this manufacture under an arrangement with the dyestuff industry, but if the latter prefers to make its own caustic soda, as recommended by us, caustic potash manufacture could also be undertaken.

Ammonia : Our total requirements of liquor ammonia (0.88 sp. gr.) are about 250 tons annually, assuming the recovery of excess of the reagent used in the amination processes. This is large in comparison with the small production of ammonia at present. The supply problem is discussed later in conjunction with our requirements of anhydrous ammonia.

Salts : Our major requirements are common salt (10,000 tons) and sodium sulphide (2,500 tons), followed by sodium acetate (500 tons), copper sulphate (400 tons), sodium sulphate, both anhydrous and hydrated (200 tons of each), sodium nitrate (200 tons), sodium dichromate (1,000 tons) for manufacture of anthraquinone by oxidation of anthracene or alternatively aluminium chloride (500 tons) for the other route to anthraquinone.

Common salt : This is required in large quantities in the manufacture of dyes for various operations such as salting out soluble dyes. The exact figure of requirements cannot be easily calculated for want of sufficient data. Partial recovery may be possible. The total output of salt in India is reported to be 31,250 tons and the expansion plans are for about 150,000 tons. The necessary supply of salt can therefore be easily obtained.

Sodium sulphide : This is essential for the manufacture of sulphur colours, such as sulphur black, which are very popular in the market and have a large sale. It is moreover required for the application of these dyes to textile fibres. The manufacture of this chemical in India has not been developed, nor are there any definite plans for the future. Attempts were made since the outbreak of the war by many firms to produce sodium sulphide, but little success has been attained till now. The raw materials used are either salt cake or natural sodium sulphate, large supplies of which are found in Jodhpur State. Immediate steps must be taken towards the indigenous manufacture of this important chemical.

Sodium (or potassium) dichromate : About 1,000 tons are required if anthracene is used as the starting material for the preparation of anthraquinone. It was not being manufactured in India before the war, but the present capacity of Indian factories is estimated to be about 3,600 tons, and it may be possible to increase the output by ten per cent. The pre-war consumption in India was less than 1,000 tons, being mainly used in the textile, leather and paint industries, and the dyestuff industry can depend on Indian production for the supply of dichromate.

Sodium acetate : Required in both the hydrated and the anhydrous forms, the import figures have not been published, but it is known that substantial amounts are used in the textile industry. The only present source

of raw material for its manufacture in India is grey acetate of lime from Bhadravati. The problem as a whole may be considered from the viewpoint of the manufacture of acetic acid and its compounds, but the quantity of sodium acetate required for dyes is too small for the industry itself to take up its manufacture.

Sodium nitrite : This is a noteworthy requirement of the dyestuff industry for the preparation of azo dyes. It is also used by the dyer to some extent for diazotising Fast Bases in naphthol dyeing, although there is a preference for the ready-made stabilised diazo salts which simplify the work of the dyer and eliminate the diazotisation stage ; the import of nitrite seems to have been a minor item, as it is not listed separately, in the Accounts relating to the sea-borne trade of India. Sodium nitrite, once produced by reduction of the nitrate with lead or a mixture of carbon and lime, is now almost exclusively made in the course of the processes for the fixation of atmospheric nitrogen by absorption of nitrogen oxides in alkali. We recommend that sodium nitrite should be manufactured as a by-product from the manufacture of nitric acid by ammonia oxidation.

Sodium bisulphite, thiosulphate and hydrosulphite : Although none of these is manufactured at present in appreciable quantities, their production in India should ordinarily not present any difficulties. Sodium bisulphite can be recovered from the sulphuric acid contact plant, while sodium thiosulphate is a recovery in the manufacture of sulphur black. While the quantitative requirement for the dyestuff industry is small (40 tons), hydrosulphite is an important chemical for the purification of certain vat dyes. It is also required in the textile and sugar industries. Since the vat colours constitute the most important group of all synthetic dyes, the manufacture of hydrosulphite on a scale of about five tons a day may be taken in hand by the dyestuff industry. In the alternative, Tata Chemicals may undertake its manufacture, as zinc chloride, which is made by them, can be conveniently linked up with the production of hydrosulphite by zinc reduction of sulphurous acid.

Sodium (or potassium) chlorate : Its importance is as a raw material for the match and explosive industries. Although no reliable information of its manufacture in India has reached us, it is said that a match factory near Bombay has set up a plant with a daily capacity of ten tons for the production of the potassium salt. The average pre-war consumption was nearly 1,600 tons. Our requirements are comparatively small (ten tons) and should be met by a producer for the match industry.

Aluminium chloride : Anhydrous aliminium chloride is required in large quantities (500 tons), mainly for the manufacture of anthraquinone from phthalic anhydride and benzene. It is prepared by the direct action of chlorine (or hydrogen chloride) on metallic aluminium, or by a cheaper method using alumina and coal in place of aluminium. Alumina is available in large quantities in India. Anhydrous aluminium chloride is difficult to store and transport, and it is best used immediately after preparation. The dyestuff industry should therefore make its own aluminium chloride.

Potassium compounds : Potassium nitrate is required to the extent of about 100 tons. Large quantities are available in Bengal and the Gangetic plains, and the annual production is about 15,000 tons.

Potassium chloride, of which only fifteen tons are required, is available.

Zinc chloride is required for the manufacture of zinc double salts of some basic dyes. One firm has planned a large production (1,000 tons), but

we have been importing 1,000 tons for the textile industry, in which it is employed as an antiseptic in sizing. The zinc chloride requirement for the dyestuff industry is only about 65 tons, and could be made available from indigenous production.

Phosphorus compounds : The chlorides (50 tons) and the oxychloride (5 tons) are invaluable reagents for the preparation of acid chlorides, which play an important part in organic synthesis. The production of these must be necessarily preceded by the manufacture of elemental phosphorus, which again is a part of the larger question of the development of the fertiliser industry. The import of phosphorus chlorides from foreign countries is inconvenient on account of their fuming and corrosive character, and attempts must be made towards the timely establishment of their production.

METALS :

Iron : Iron is by far the most important requirement (500 tons), being largely used in the various reduction reactions. It is required in the shape of cast iron borings of about three-eighths inch mesh. These borings are the by-product of the textile machinery manufacturing industry, or of the manufacture of machines such as typewriters and telephones. Investigations will have to be made as to the availability of such borings in the required quantities.

Zinc is not produced in India and has to be imported.

Non-metals : One of the outstanding demands is for *sulphur*, used mainly in the manufacture of sulphur dyes, apart from its use as a raw material for sulphuric acid, hydrosulphite, etc. Our total sulphur requirements in India are large, the import being 28,500 tons. The requirements of the dyestuff industry are 750 tons for sulphurisation processes for dyes, and 4,778 tons for inorganic sulphur compounds, such as sulphuric acid and hydrosulphite. It must be noted that while the sulphuric acid and allied industries could turn to other sulphurous materials such as pyrites, crude sulphur or gypsum, the production of sulphurous dyes requires pure elemental sulphur.

While the present indigenous production of sulphur as sixty per cent. rock from the Baluchistan deposits amounts to 24,000 tons and can be expanded, it is doubtful if sulphur of the required purity can be obtained at a reasonable price after the war from this source.

Chlorine : This is required to the extent of 800 tons. While the production of chlorine including the expansion in view is many times the quantity required, the actual availability would be a very different matter, and has to be carefully examined in view of the other demands on chlorine. It follows from our recommendation regarding caustic soda that the dyestuff industry should make its own chlorine.

Oxides : Most of these are available in large quantities in India from natural sources, but treatment of the ores, e.g., by froth flotation, may be necessary to improve the quality of the ore according to our requirements.

Gases : Among gases the only one not being manufactured is phosgene. Carbon dixoide is available in plenty as a by-product from fermentation industries. Sulphur dioxide could be procured from the sulphuric acid plants. Hydrogen is a by-product in the manufacture of chlorine, and the dye manufacturer will find it an advantage to undertake the simultaneous production of the two.

A major problem is the supply of ammonia, especially for its oxidation to nitric acid. About 450 tons are required and this again could be obtained only if we have a well developed nitrogen fixation industry. One of the factors in the ultimate economy of dyestuff manufacture is the establishment of a nitrogen fixation industry. The establishment of this industry at an early date, under Government auspices if necessary, must be regarded as very likely, as the provision of a cheap and abundant supply of fertilisers for improving the productivity of the soil is one of the most essential requirements of the country. The industry moreover is of national importance and India should no longer be made to depend upon foreign imports for the supply of nitrogenous fertilisers.

Coal-tar raw materials : There are many considerations regarding the position of coal-tar raw materials, which do not apply to the inorganic chemicals. The most important difference is that the production of coal-tar, and consequently of its products, is entirely dependent on the extent of the by-product coking carried out in India. Carbonisation of coal cannot be carried out merely for the recovery of coal-tar in the absence of a corresponding demand for coke. Thus in contrast to the inorganic chemicals, the production of coal-tar cannot be increased according to the demands of the dyestuff industry, but on the other hand the dyestuff industry will be limited in respect of its output by the supply of the coal-tar hydrocarbons from the by-product coke industry.

Bulk supplies of Indian tars are obtained from the by-product coking ovens which produce metallurgical coke for the iron and steel industries. The coals employed are comparatively limited in range, belonging to the type of coking coals, and the temperature of carbonisation is the highest possible in the ovens. Hence the tars may be expected to be of approximately uniform composition, and this would appear to be true of the tars of Bhowra, Bararee Coke Company and Giridih. There is, however, another group of coking plants, the tars from which differ materially on account of the special quality of the coals used, or the design of the plants, or the conditions of operation. Tars of the second type are produced by the Tata Iron and Steel Company, Indian Iron and Steel Company, Turner Morrison & Co. at Lodna, and Bird and Company at Loyabad. Tars of the gas companies in Bombay and Calcutta will represent a third type.

In spite of the small number of plants working in India, there are considerable difficulties in obtaining data regarding the tar products. The terminology used for the fractions varies from factory to factory. There is considerable intermixture of the products of different companies. The combined result of these factors is that it is not possible to obtain entirely reliable data of past and present production, possible increase in output, and the isolable quantities of the raw materials required by the dyestuff industry.

The tar industry in India can be divided into two broad, well defined groups. The first consists of the tar producers who carry out the carbonisation of coal. The bulk of the metallurgical coking industry is in the hands of two large concerns, but other plants also produce metallurgical coke in by-product ovens, and there are two gas companies. Figures of the production of coal tar in India are given in Appendix XVII.

The second group includes the tar distillers who are mainly concerned with the subsequent treatment of tar in stills and the distribution and sales of the tar products so obtained. The companies engaged in the distillation of coal tar are listed in Dr. Forrester's report. Each of the two sections of the

tar industry has an association to control and regularise trade policy. The most important members of the tar producing companies (i.e., the metallurgical coke and the gas companies) are members of a trade organisation known as the Tar Producers' Association, whose declared object is to pool tar resources for distribution under a common policy to the various tar distillers. The major interests in the combine are Tatas and Indian Iron and Steel Company whose combined annual output is 87.5 per cent. of the tar from metallurgical coke oven plants and 82.5 per cent. of the total tar produced in India.

The other trade association is the Coal Tar Distillers' Association, whose members are the Shalimar Tar Products (1935) Ltd., the Bengal Chemical and Pharmaceutical Works and the Bararee Coke Company. The Association controls the general policy of the output of different tar products depending on the demands of the trade.

A reference to the position of road tar in India and the relevant policy of Indian tar distillers is necessary. The most important products of the distilleries are creosote and road tar. The production of grades of road tars in accordance with the requisite specifications involves the treatment of tars in such a manner that only a very small part of the valuable constituents are recovered. The road tars manufactured in India mostly conform to the British Standard Specifications with slight modifications.

In connection with the problem of recovering a larger amount of the valuable products for use in the dyestuff and other industries, the possibilities of modifying the specifications of road tars should be considered, so that they will contain less of such fractions. It should not be impossible to do so without destroying the value of the tars for road purposes.

Benzene : The total requirement of the dyestuff industry is about 400,000 gallons, the whole of which should be of high purity for nitration and other reactions, and should satisfy strict specifications. The main uses of benzene are for the preparation of nitrobenzene, chlorobenzene and phenol. Larger amounts of benzene will be required if the production of synthetic resins is taken up in India, for which purposes more phenol will be necessary.

Benzene is not principally derived from tar, but from coal gas. The bulk of this hydrocarbon, as well as toluene, is recovered from raw gas by extraction.

Benzol is at present recovered from coal gas only from the following plants in India :—Bararee, Giridih, Tatas and Indian Iron and Steel Company. No benzol is recovered from the plants at Loyabad, Lodna and Bhowra. Including the present and the planned production, the total annual output comes to 2,417,000 gallons of 90's benzol. The figures supplied have not in all cases distinguished clearly between benzene and benzol. The production from Bararee is 70,000 gallons of toluene-free benzene per year. It is understood that proposals for the recovery of benzol by installing the necessary plants are afoot in the coke plants at Bhowra, Lodna and Loyabad. Assuming a minimum recovery of even fifty per cent. benzene from benzol, the capacity for the pure hydrocarbon would be 1,200,000 gallons, which is thrice the requirements of our Plan.

Toluene : The requirement of the dyestuff industry is about 125,000 gallons. Large amounts are being recovered in the pure state for nitration in the manufacture of explosives. The production of nitratable toluene is stated to be about 170,000 gallons, which could be increased to nearly 347,000 gallons by the fractionation of more benzol. Till the outbreak of war the

demands of pure toluene were being met by imports, mainly from Germany. The present position is favourable for the dyestuff industry.

Naphthalene : Our requirements of naphthalene, even taking into consideration the alternative route to the synthesis of anthraquinone and its derivatives, are about 1,000 tons. The present production of naphthalene is said to be about 1,100 tons, which can be increased considerably if desired.

Anthracene : Anthracene is the only coal tar raw material of which the supply will be inadequate. The total planned production of anthracene is 120 tons at present ; this is only the crude product with about forty per cent. anthracene content (or less), the rest being carbazole and phenanthrene. The total requirements of pure anthracene are about 500 tons and a supply of about fifty tons is perhaps all that can be depended on. A considerable increase might become possible if more tar distilleries worked up the anthracene oil. The problem of manufacturing pure anthracene in sufficient quantities will, however, remain. The total production of coal-tar in India has been estimated to be about 100,000 tons. The anthracene content of tar is usually about 0.1—0.3 per cent., and if all the tar were treated by the most efficient method for anthracene recovery, about 100–300 tons of pure anthracene would be obtainable. This yield, however, is likely to be impracticable. Moreover, the recovery of pure anthracene from crude anthracene requires very large quantities of pyridine. The reported production of pyridine is a negligible figure (225 gallons). A method for the preparation of pure anthracene from the crude material not involving the use of pyridine has recently been worked out in the Department of Chemical Technology at Bombay and would appear to be capable of practical application, but under the best conditions it would be safe to examine alternative sources of raw materials for anthraquinone dyes.

Difficulties in utilising coal-tar anthracene are not peculiar to this country. Anthraquinone is the first stage in the conversion of anthracene to both mordant and vat colours, and anthraquinone can be conveniently prepared by the condensation of phthalic anhydride and benzene in presence of aluminium chloride, and cyclising the *o*-benzoylbenzoic acid with sulphuric acid. The ready availability of phthalic anhydride by the air oxidation of naphthalene in the vapour phase with vanadium pentoxide as catalyst is well known, and the naphthalene route to anthraquinone is finding increasing favour, although not in England.

Calculating the data for the raw materials for manufacturing five hundred tons of anthraquinone, required by the dyestuff industry, by this method, it was found that they were about 400 tons of naphthalene, 170 tons of benzene, 600 tons of anhydrous aluminium chloride, 570 tons of caustic soda and 330 tons of concentrated sulphuric acid. Recovery of sulphuric acid has been taken into account. The total naphthalene requirement will thus be increased to about 1,000 tons, as against the production of 1,088 tons ; the naphthalene capacity must therefore be expanded by fifty per cent. or more to allow for the demand as moth balls. The import of naphthalene, mostly in this form as a preservative, has been about 400 tons.

Carbazole : A by-product in the manufacture of anthracene from coal-tar, our requirement of carbazole is fifteen tons. It is not produced at present in India, but Indian anthracene is rich in carbazole and no difficulty in its availability need be anticipated.

Pyridine : Pyridine is used as a solvent, as an organic base, specially in the manufacture of the solubilised vat colours, and as a denaturant for

industrial alcohol. Considering the recovery possible, the requirement is nine tons or about 2,000 gallons, while the planned production is only 225 gallons. The problem of stripping Indian coal tar entirely of its pyridine content must be taken in hand without delay.

Solvent naphtha : The total requirements of solvent naphtha are 4,000 gallons, compared with the production of 288,500 gallons. It is also reported that the output can be increased if a demand arises. The supply for the dyestuff industry is not only assured but, as in the case of toluene, further avenues for its utilisation must be explored.

Phenol : While phenol is being increasingly manufactured by synthetical methods, it is also recovered to some extent directly from tar. The total production of tar acids in India is stated to be 26,000 gallons, but it can be increased to 62,000 gallons. Tar acids are in great demand at present, and also in peace time. The normal civil demand is about 400 tons, and the War Department requires 100 tons. Phenol is used in the dyestuff industry, the synthetic drug industry, the manufacture of synthetic plastics such as Bakelite, and for miscellaneous purposes (treatment of lubricating oil, leather, etc.). It is estimated that the synthetic plastics industry, if started, would alone absorb 500 tons of phenol in the initial stages. The total demands at present, both civil and military, are about 1,200 tons and an increase is expected.

Aliphatic raw materials : Among our major requirements of these are methyl and ethyl alcohol. In addition, we require appreciable quantities of formaldehyde, glycerine and acetic acid, both as forty per cent. acid and in glacial form.

Methyl alcohol : About 80,000 gallons (286 tons) are required. The only source of methanol in India is the wood distillation plant at the Mysore Government Iron Works at Bhadravati. The total production amounts to 420 tons. The by-product recovery plant at Bhadravati is operated mainly for meeting the demand for acetates. It is reported that the War Department has erected a plant for manufacturing acetone from alcohol, and methanol will no longer be available from Bhadravati as the by-product plant is closing down. The present civil requirements are stated to be 200 tons, ninety per cent. being used for denaturing industrial ethyl alcohol and ten per cent. as solvent. The defence demands are also very large, being about 420 tons for conversion into formaldehyde, etc. Thus, even in normal times, there will be an appreciable demand for methanol from sources other than the dyestuff industry. So far as that industry is concerned, it can import its requirements, if it is not available locally at a reasonable price ; but it is recommended that the production of synthetic methanol should be undertaken in India.

Ethyl alcohol : The requirements are 35,000 gallons (125 tons) of the ordinary quality and 10,000 gallons (36 tons) of absolute alcohol. The main application is as a solvent, but in the dyestuff industry it is also used for the preparation of the ethyl anilines.

It is manufactured on a large scale in India by the fermentation of molasses and mowrah flowers. The total pre-war production was 7,000 tons, being locally consumed as a potable spirit and in the pharmaceutical industry. There is a large demand for it at present, about 19,000 tons for civil purposes and in addition very large quantities are required for transport, both civil and military. The present production is stated to be about 28,500 tons, and all the distilleries are working up to their maximum capacity. Absolute alcohol

is also being made in a few factories, notably by the Mysore Sugar Company at Mandya. The demands of the dyestuff industry are small, compared with the requirements of the pharmaceutical industry and as power alcohol.

Acetic acid : Used as a solvent and as a reagent in the preparation of acetyl derivatives, our needs are fifty tons of the forty per cent. acid and a hundred tons of glacial acetic acid. In addition a hundred tons of acetic anhydride are required. Acetic acid is manufactured by several methods, among which the most important is the catalytic oxidation of ethyl alcohol. Until very recently the only source of the acid in India was the pyroligneous liquor from the wood distillation plant at Bhadravati, from which it has been recovered in the form of grey acetate of lime ; but it is understood that steps are being taken for the production of acetic acid from alcohol. We recommend that the manufacture of synthetic acetic acid on an adequate scale should be organised as early as possible.

Glycerine : This is a vital requirement of the dyestuff industry, being used in the preparation of benzanthrone, an important intermediate. The requirements of the plan are 100 tons. The total pre-war consumption of glycerine was 850 tons, whereas the total production was only 650 tons. On account of the recovery effected by two of the leading soap manufacturers in India, the present production is estimated at 1,850 tons, as against the demands for 800 tons for civil use and 1,950 tons for the manufacture of explosives. The main applications of glycerine in civil life are in the pharmaceutical and textile industries, and it is evident that the necessary supply for the dyestuff industry will be forthcoming after the war.

Formalin : Formalin (40 per cent.) is required to the extent of about 20 tons, and although this quantity is being produced in India, it is estimated that 1,000 tons will be necessary for the manufacture of synthetic plastics. While the requirements of the dyestuff industry will not justify the erection of a separate plant for the production of formalin, it is recommended that the manufacture of formalin from synthetic methanol should be organised as early as possible.

Turkey Red Oil : The requirement is only a few tons in comparison with the large amounts used in the textile industry and manufactured in the country. In view, however, of the wide variations in the quality of Turkey Red Oil (and more highly sulphonated oils, such as Monopole Soap, Monopole brilliant oil, Prestabit oil, etc.) produced in numerous small factories, it is desirable for the new dyestuff organisation to include in its programme the production of standard types of the sulphonated oils.

In connection with the above survey of raw materials, we have met with considerable difficulties in securing data in spite of the ready assistance of a number of officials and private bodies. Figures are required not only of the actual production, capacity and contemplated expansion of production of the individual chemicals in Government as well as private concerns, including munition works, but also of the probable consumption, in the near future, by Government departments and private industries. We suggest that Government should institute an accurate survey, through its own officers fully authorised to call for information from all sources, regarding the production and consumption of chemicals in India.

Following this survey of all the important raw materials required for an Indian dyestuff industry, the *inorganic chemicals* may be divided into four groups : (i) those manufactured in India and available ; (ii) manufactured,

but partly or completely allocated or produced in inadequate quantities, so that the production will have to be expanded to meet the full demand ; (iii) not manufactured in India, but required to be manufactured on account of their importance ; (iv) to be imported. To the first group belong soda ash, bromine, common salt, sodium dichromate, potassium chloride and nitrate, and iron. In the second group come hydrochloric and nitric acid, caustic soda, ammonia, sodium acetate and chlorate, and chlorine. Oleum, sodium nitrite, sulphide, sulphite, bisulphite, thiosulphate and hydrosulphite, and aluminium chloride are among the compounds in the third group. In the last group are materials, such as zinc of which India possesses no natural resources, or phosphorus compounds, potassium cyanide, selenium and iodine, required in comparatively small quantities. Sulphur, though needed in large quantities, may have to be included in this group if the Indian deposits are found unsatisfactory.

Coal-tar raw materials : The three essentials are benzene, toluene and naphthalene. Benzene and toluene are available in quantities considerably larger than those required. The present supply of naphthalene is somewhat inadequate, but can be increased without difficulty. About a third of the anthracene requirement may be available, and the need for the remainder may be obviated by using the naphthalene route to anthraquinone. Carbazole can without doubt be isolated in the necessary quantity by working up the residues in the refining of crude anthracene. Pyridine (about 2,000 gallons) might have to be imported, but the possibility of isolating it from Indian tar must be examined.

Aliphatic raw materials : (1) The position regarding methanol is somewhat doubtful, though the production is larger than our requirement for the dyestuff industry, but less than the sum of this figure and the total civil demands. It may have to be imported if not available at a reasonable price. (2) The requirements of ethyl alcohol can be easily met from the large Indian production. (3) Acetic acid will have to be imported at least in the early stages. (4) The supply of glycerine is ample. (5) There is a shortage of formalin even for civil demands.

On a general survey of the raw material position, we come to the conclusion that it is reasonably satisfactory, though there are problems regarding the scale of production, the availability of some of the chemicals and, above all, the prices. So far as our inorganic requirements are concerned, most of them are being manufactured in India. The problem in the case of some is that of increasing their production to meet the needs of the dyestuff industry. In the case of vital requirements such as sulphuric acid, hydrochloric and nitric acid, caustic soda and chlorine, the dyestuff industry should manufacture them itself. In the case of others scarcely less important, such as caustic potash and sodium sulphide, the industry may try to make arrangements with the existing manufacturers of heavy chemicals. We do not feel that it would be difficult to arrive at such an arrangement in the mutual interests of both. Failing such an arrangement, the dyestuff industry will have to manufacture these chemicals itself.

An important consideration to be borne in mind not only in connection with inorganic chemicals, but also with regard to all other raw materials, is the time factor. In the early stages of the establishment of the industry it will be necessary to import a good many of the raw materials which it should be found feasible at a later stage to manufacture in the country itself. There is bound to be considerable industrial development, including

the development of the chemical industries, after the war. It is likely, therefore, that materials required for the dyestuff industry, which are not being produced now or which are being produced in very small quantities, may be produced in adequate quantities after some time. The dyestuff industry and the heavy chemical industry are mutually interdependent and the development of both should proceed hand in hand. The same remarks apply to the manufacture of intermediates. While in the early stages most of the intermediates may have to be imported, we are of the opinion that, within a period of ten years, India will be in a position to manufacture practically all the intermediates required for a full-scale dye industry.

The existing position regarding the prices of many of the raw materials actually available in the country appears to be depressing. The normal pre-war prices prevailing in India would undoubtedly have to be lowered very considerably before the finished dye can be marketed in competition with the imported product. In Appendix XVIII of the Pai-Venkataraman Report, the foreign prices (United Kingdom and U.S.A.) of some important inorganic and organic raw materials, taken from *Industrial Chemist*, *Chemical Trade Journal* and *Chemical and Metallurgical Engineering* are tabulated in order to provide an indication of the prices at which the Indian-made materials should be available in bulk for the purposes of the dyestuff industry. In the following table, the normal prices of nine chemicals in India and in the United Kingdom are listed. It will thus be noticed that the only chemical for which our price would compare favourably is toluene. Pure nitratable benzene is priced in the United Kingdom at one half. Differences are even larger in the case of the inorganic heavy chemicals. Hydrochloric acid costs less than one-third, caustic soda less than one-half and caustic potash about one-fifth in the United Kingdom in comparison with the Indian prices.

Product		Prices in Rupees	
		India	U.K.
Pure benzene	per gallon	2-12-0	1-5-0
Pure toluene	,,	2-4-0	2-8-0
Naphthalene	per cwt.	24-0-0	13-0-0
Sulphuric acid (168° Tw)	per ton	117-0-0	70-0-0
Hydrochloric acid conc.	,,	255-0-0	80-0-0
Nitric acid conc.	,,	390-0-0	260-0-0 to 330.
Caustic potash	,,	3,000-0-0	640-0-0
Caustic soda	,,	400-0-0	190-0-0
Soda ash	,,	135-0-0	80-0-0

The problem of price is mainly one of supply. So long as chemicals are manufactured in small quantities to meet only some special requirements, their prices will continue to rule high, but if their manufacture is enlarged to meet the requirements not only of the dye industry but of other industries which are likely to come into existence in the post-war period, the prices will come down. We do not see, for instance, any reason why prices of caustic soda and soda ash, which would be required for a number of other industries besides dyestuffs, should continue to be so disproportionately high in India as compared with the U.K.

PLANT AND EQUIPMENT FOR THE DYESTUFF INDUSTRY

The availability of the raw materials is the essential condition for the establishment of a dyestuff industry. The varied and specialised plant required for the conversion of a coal-tar hydrocarbon to a dye constitutes at first sight a difficult problem, but it is easier of solution, because the

requirements could be met by import to whatever extent it is necessary. A detailed examination of the many and varied types of equipment required for the manufacture of the 51 dyes in our plan is beyond the purview of this Committee, but a brief indication may be given of some of the outstanding aspects of the problem, which may be referred to the Chemical Plant Committee of the Board of Scientific and Industrial Research, if necessary.

The design of equipment for the synthetic organic industries has been based upon new conceptions of the multifarious reactions carried out in the course of manufacture. These reactions, apparently widely differing from each other, have been observed to follow a certain set of general rules and have been condensed and grouped as a small number of unit processes in organic synthesis. The design of equipment for a particular reaction is now carried out in the light of the experience accumulated in the operation of these unit processes, such as nitration and sulphonation. The following is a list of the major reactions which are involved in converting coal-tar hydrocarbons into dyes :

Sulphonation : Monosulphonation ; Trisulphonation
Neutralisation with lime, soda ash, etc.
Sodiation
Reduction
    Iron and acid
    Catalytic
    Sodium sulphide
Alkali fusion
Acidification
Decolorisation
Crystallisation
Acetylation
Benzoylation
Chlorination
Bromination
Alkoxylation
Alkylation
Amination
Phenylation
Carboxylation
Nitrosation
Condensation
Hydrolysis
Benzidine transformation
Coupling
Oxidation
    Dichromate
    Manganese dioxide, etc., etc.
Condensation with phosgene
Catalytic oxidation
Salting out.

In addition to these unit reactions which require suitable equipment for the specific purpose, the manufacture of dyestuffs includes another group of physical operations to process the materials obtained from each of the unit operations of organic synthesis. These may be defined as the unit operations of chemical engineering such as distillation, filtration, grinding and mixing. Suitable machinery and equipment will have to be provided for these purposes.

Other auxiliary equipment : In addition to the multifarious plant and equipment required for the unit processes of organic synthesis and the unit operations of chemical engineering, auxiliary units such as fully equipped workshops and laboratories, boiler houses and power houses will be needed. Plant for the treatment of water may also be required. Motor generator sets, vacuum pumps, blowers and compressors, conveyors and elevators are further examples.

The dyestuff industry may have to include in its plan a modern contact plant for the manufacture of high strength oleum, plant for the oxidation of ammonia to nitric acid, electrolytic cells for the manufacture of hydrogen, plant for the recovery of spent acid after denitration, stills for the recovery of ammonia and volatile solvents, and plant for the manufacture of chlorinated solvents.

In the matter of plant, two alternatives are open to the dye industry. It can either enter into a working arrangement with an important firm or group of dye manufacturers in Europe or America, in which case the design will be furnished by the foreign firm. Such of the equipment as cannot be manufactured in India will be imported in accordance with the advice and specifications of the foreign experts, while the rest will be made in India. In the alternative, the Indian dye industry can engage the services of distinguished European or American experts in the dye industry as consultants who would then design and prepare the specifications of the necessary plant and equipment which would be imported or made in India in accordance with their advice. It may be pointed out, however, that India now possesses facilities for the fabrication and manufacture of a good deal of equipment which only a few years ago would have been regarded as impracticable. The equipment manufactured in the workshops of Messrs. Tata Chemicals at Mithapur with comparatively moderate resources is an instance in point. It would be of benefit both to the engineering industries in India and the dyestuff industry to create a chemical engineering industry with factories specialising in the fabrication of autoclaves, glass-lined or acid-proof enamel equipment, etc.

LOCATION OF THE DYESTUFF INDUSTRY

The selection of a suitable site for locating the dyestuff industry is among the factors that will decide the success of the plan. The choice is governed by a variety of considerations on account of the special characteristics and complicated requirements of the industry. It is not possible to suggest any definite location for the Indian industry without a detailed examination of possible sites and all that we can do in this report is to indicate some broad considerations which govern the problem of location. The ultimate choice of a site should form the subject of a special examination aided by experts who have had practical experience of the requirements of the industry in other countries.

The products of the dyestuff industry have a comparatively high unit value as opposed to the heavy chemical and other related industries. It needs many raw materials widely differing in nature, such as the inorganic acids, alkalis and salts, non-metals and gases, the organic coal-tar hydrocarbons and the aliphatic solvents ; and it is obvious that all these can never be produced at one spot in any country. The total weight of raw materials needed for the plan is many times the weight of the total output of products. Another consideration is the neighbourhood to the great dye-consuming centres.

The outstanding factor which would ultimately decide the issue is the basis on which the industry is to be organised in relation to the coal-tar distillation, heavy chemical and the dye manufacturing interests. If the bulk of the heavy chemicals is to be produced by the dyestuff manufacturer himself, the location would then depend on the general advantages of the site and neighbourhood to the main textile centres. It may be of interest, however, to examine briefly the data collected regarding the raw material requirements in relation to the location of the dyestuff industry in India. The relative amounts of inorganic chemicals, coal-tar raw materials and aliphatic compounds (solvents, etc.) are as follows :—

	Tons	Tons
Inorganic chemicals :		
Solids	21,000	
Liquids	18,200	39,750
Gases	550	
Coal-tar raw materials :		
Solids	1,350	
Liquids	1,950	3,300
Aliphatics (Alcohols, acetic acid, glycerine, etc.)		
Liquids	900	900
Total ..		43,950

These figures represent the approximate total annual consumption, but materials to be handled annually in the plants will be far greater than these quantities, and the major part of the difference again will be the inorganic chemicals.

It is evident that the total quantity of the coal-tar raw materials to be transported to the site of the dyestuff industry is only about seven per cent. of the total tonnage to be transported, while the inorganic chemicals will constitute over ninety per cent. Among the inorganic requirements, a dozen heavy chemicals (sulphuric, hydrochloric and nitric acids, common salt, caustic soda and potash, soda ash, sodium sulphide, sodium nitrate and nitrite) form the main bulk of the total.

Another feature regarding the organic raw materials on the one hand and the inorganic chemicals on the other is the comparative ease with which the former can be handled in transport and storage. The coal-tar raw materials are mainly the two liquids, benzene and toluene, which can be transported in tank cars or tank trucks and run by pipe-lines into underground storage

tanks from a distant railway siding. Naphthalene, anthracene and carbazole are three solids easily handled in wagon loads.

The problems of handling and transporting the many different inorganic chemicals are much more complicated. The liquids are mostly acids which are highly corrosive. The solids are numerous and varied in character, and some are hygroscopic and unstable in the presence of moisture, the decomposition also causing corrosion of the containers. Transport over long distances of large quantities of concentrated and fuming acids, phosphorus and sulphur chlorides, bromine, etc., will involve excessive freight charges, and difficulties regarding containers.

Judged by the availability of raw materials, the most convenient location for a dyestuff industry would appear to be in the neighbourhood of a heavy chemical production centre. If, however, the dyestuff industry is so organised that the necessary inorganic chemicals are manufactured by the industry itself, this consideration will become less significant. Moreover, it is important to examine very carefully the advantages of location near the great consuming centres which by comparison may render other considerations less decisive.

There is perhaps no industry in which closer co-ordination and contact between the manufacturer and the consumer are necessary than the dyestuff industry, including its subsidiaries such as production of textile auxiliary agents. Food and clothing being the two primary needs of our vast population, the textile industry will always continue to be our premier organised industry. The demands of the millions of users of cloth are naturally of a varied character and the textile processor has therefore to be in constant touch with the dyestuff manufacturer, if only through the sales organisations. The application of dyes to yarns and fabrics produced from numerous types of cotton and of many different qualities is a difficult and complicated process, which is not capable of simple standardisation. Difficulties arise continually, and the bleacher, dyer and printer need the expert assistance of the tinctorial and textile chemists with knowledge and experience of the chemistry and technology of dyes and allied products. It is well known that the dyestuff organisations, such as the I.G. and I.C.I., maintain extensive laboratories in Bombay and smaller ones elsewhere to render technical service to the textile industry. It would be a satisfactory arrangement if the dyestuff industry were so located that the laboratories, which it would anyhow have to maintain in order to test its products at every stage, could be made available for the purpose of the dye consumer.

Another consideration which would have an important bearing on deciding the ultimate location of the dyestuff industry is the neighbourhood of a port on account of the advantages in securing the cheap import of plant and machinery, as well as of the chemicals required for the industry.

Among other factors which must be taken into account is the existence of adequate sources of water supply which in view of the large consumption of water involved in the manufacture of dyestuffs may well prove of considerable importance.

The Committee has not surveyed suitable sites and the ultimate choice will doubtless have to be made by a special committee of experts. From the evidence before us, however, we are of opinion that the most suitable location for the dyestuff factory will be in the neighbourhood of Bombay City or the coal-fields area.

THE ORGANISATION OF THE DYESTUFF INDUSTRY

Our last term of reference is " to consider the practicability, both technical and economic, of establishing a dyestuff industry in India which would ensure the manufacture of all such intermediates and dyes as are feasible within a period of fifteen years." We have now considered the availability of the various raw materials required for the establishment of the industry in India and have come to the conclusion that, in spite of difficulties which can only be obviated as India expands industrially, it would be possible to make an immediate start with the establishment of the dye industry in the country. In the earlier part of this report we have suggested the manufacture of 51 dyes for a start. The reasons for our selecting the particular dyes have already been mentioned. We consider that after the preliminary period of preparation of about two to three years depending upon wartime and immediate post-war conditions, it would be possible to establish the industry on such a basis as to manufacture the 51 dyes within a period of five to six years. In the earlier stages, most of the intermediates will have to be imported, although there is no reason why some of them could not be manufactured from the start. If, for instance, the industry were to begin with the preparation of azo dyes and Brenthols, *Beta*-naphthol and Hydroxynaphthoic acid could be manufactured.

It is extremely difficult to give an estimate of the cost as it will depend upon a variety of circumstances which cannot be foreseen. A very rough estimate for the 51 dyes which are planned to be produced in the first stage would be rupees five and a half to six crores. This would, however, be on the assumption that almost all the intermediates will have to be imported. If the intermediates are also to be manufactured, the estimate will have to be doubled. This, however, would not be economic. If we adopt the policy of manufacturing all or a majority of the intermediates simultaneously with the manufacture of the dyes, the result would be either that we would have to put up large plants such as would be ultimately adequate for the production of the whole range of dyes, in which case they would be uneconomic in the earlier stages, or small plants suitable for our immediate requirements, the small-scale production of which would again be uneconomic. The small plants will have to be scrapped in favour of full-scale plants as the range of production increases. In either case such a policy would not be economic. It is, therefore, suggested that, during the first five or six years, after the preliminary preparatory stage, when the 51 dyes are manufactured, most of the intermediates should be imported. We are of the opinion that, after this stage is reached, it would be possible to proceed further with the manufacture of all the dyes in substantive demand in India and that such manufacture could be established within a period of fifteen or twenty years after the preparatory stage. At that time it would also be necessary, and indeed eminently advisable in the interests of the country, to manufacture the intermediates. For obvious reasons it is not possible to make an estimate of the total cost, but a very rough estimate of the total cost of manufacturing all the dyes and intermediates required by the country would be rupees twenty-five crores. Certain important considerations have, however, to be borne in mind. We have seen from the history of the industry in other countries and the very difficult and complex nature of the processes involved that it is essentially an industry in which no single country can be entirely independent and self-contained. If India were to attempt to be entirely independent of the outside world, it would have slowly and laboriously to acquire the experience which others have already acquired. In that event

it would not be possible to establish the industry within the time or at the cost mentioned above. If, on the other hand, India were to come to an agreement for co-operation with a large and well established concern in Europe or America, so that its technical experience and expert advice were available to it at every stage, the establishment of the industry on the lines mentioned above would be feasible. Such co-operation should not, however, be in any way at the expense of Indian interests. Any company or companies that may be formed on this basis must have a majority of Indian capital and Indian directors and an agreement should be definitely made for the training of Indian technical personnel from the highest to the lowest, so as to enable Indian personnel to direct the conduct of the industry within a reasonable period. The control of policy should always remain in Indian hands.

The dyestuff industry is one of such basic importance in the economy of a country that, consistently with any arrangements for co-operation with other countries which may be found necessary in the interests of the industry, the national character of the industry should be preserved and safeguarded. The products of the industry are of vital importance to a country—alike in peace and in war—and it is therefore essential that Government should maintain a careful watch over its progress and activities with a view to ensuring that the national interests involved are not in any way jeopardised.

An alternative to this would be to have no direct association with any foreign dyestuff interests, but the engagement of the best experts and consultants wherever available for advice and guidance of Indian interests who would be solely responsible for the establishment and management of the Indian industry. This alternative, though feasible and most suitable from the point of view of ensuring the complete independence of the Indian industry, is not so satisfactory in other directions and will not lead to such an early establishment of the industry. For one thing there are patents and processes, which are open to the large dyestuff corporations who form part of the international cartel which will not be open to the nascent Indian industry. It will not be possible for it to engage the services of all the experts who would possess a knowledge of the entire series of patents and processes which may be required.

THE ORGANISATION OF THE FEEDER INDUSTRIES

The organisation and development of the inorganic heavy chemical industry, the coal-tar distillation industry and the aliphatic chemical industry is essential for the creation and prosperity of the dyestuff industry. All the three groups of industries already exist in India, but in varying stages and degrees of development. We have to distinguish between these three industries in that they differ in their status and relation to the dye industry.

The inorganic chemical industries can be broadly divided into two important sections. One comprises the acids (except oleum), alkalis and salts, which are independent of the dyestuff industry for a market and can usually find a ready demand from other sources. The other section of the inorganic chemical industry, which is still undeveloped in India and which will mainly cater for the needs of the dyestuff industry and the synthetic organic industries in general, deals with the manufacture of oleum (specially of high SO_3 content), sulphur and phosphorus chlorides and oxy-chlorides, aluminium chloride and similar inorganic reagents and condensing agents for organic reactions. The dyestuff industry might encourage the free growth of the

first section of the inorganic industry, drawing its requirements from the manufacturers, so that it can take advantage of healthy competition among them, and at the same time save the capital cost of the necessary plant and equipment. It might in addition offer to these manufacturers of inorganic chemicals the choice of the manufacture of the second group of chemicals, if they can be made available at economic prices. It may then be necessary to give certain assurances and enter into long-term contracts. If, however, the dyestuff industry finds that there is no response from established producers of heavy chemicals and that it is inconvenient or uneconomic in any sense to buy these chemicals from outside, it must take on itself the responsibility for their manufacture and include them in its scheme of production.

So far as the five important heavy chemicals (sulphuric acid, hydrochloric acid, nitric acid, caustic soda and chlorine) are concerned, these should be manufactured by the dyestuff industry itself.

The aliphatic chemical industry can be divided into two sections : one which manufactures methyl and ethyl alcohol, formaldehyde, glycerine and acetic acid, which are largely consumed by other industries ; and the other which goes in for the production of the special solvents and aliphatics, needed primarily by the dyestuff industry.

The coal-tar distillation industry stands on a different footing. The products of this industry will be mainly for supplying the demands of the dyestuff industry. No doubt some of its products, such as toluene for explosives, benzol as motor fuel, naphthalene as insecticide and solvent naphtha as general solvent, may find a market elsewhere ; but by far the largest proportion of the output will be consumed by the dyestuff industry directly or through it by the other synthetic organic industries in the form of dye intermediates. The main cause of the backward state of our coal-tar distillation industry may be traced to the absence of a synthetic dyestuff industry in India. The dependence of the coal-tar industry and the dyestuff industry is mutual. Hence the dyestuff industry has to take an active part in the organisation of the former, and those who are concerned with the creation of the industry might find it necessary to have an active financial interest in the coal-tar industry. The establishment of coal-tar distillation on the requisite scale should be the outcome of the joint efforts of the dyestuff industry and the by-product coke oven industry. The dyestuff industry may have to encourage the coal-tar producers by entering into long-term contracts for the purchase of their products, and the coal-tar industry in its turn should assure the dyestuff industry of a regular supply of the coal-tar raw materials of adequate purity and at reasonable prices. A central plant could be set up where all the crude fractions could be collected from the smaller coal-tar works, and the pooled products could be refined on a large scale to benzene, toluene, etc., of specified purity.

Unscientific use of tar and its products : Most of the Indian tar is at present consumed for road-making purposes and for paints. The tar so used contains many constituents which are valuable for the synthetic organic industries. The wastage and uneconomic use of tar and tar products should be prevented by law.

THE INTERNAL ORGANISATION OF THE DYESTUFF INDUSTRY

This may take the form of many units with a vertical or horizontal organisation or be a completely unified centralised industry. In England and Germany, where the dyestuff industry originated, the development took

place in a haphazard way. There were many separate factories and organisations, but as we have seen, the tendency has been towards integration and unification. The creation of large combines in Germany and Great Britain has brought all the dyestuff interests under unified control. Starting as we do with a clean slate, we should take advantage of the lessons already learned. Production at several factories spread over the country will mean the setting up of uneconomic units. Once the industry develops, the question of the manufacture of intermediates assumes very great importance. The utmost efficiency is required, as a difference of a few per cent. in the yield of nitrobenzene or aniline or any falling off in their standards of purity would materially affect the production costs of the dyes. For these reasons, the case for one centralised factory, manufacturing the whole series of dyes through all the stages starting from the coal-tar raw materials, is very strong.

The marketing of dyes and textile auxiliaries is the specialised field of men with intimate knowledge of the trade, and the usual practice has been for groups of dye manufacturers to co-operate and pool their resources together, forming cartels in different countries to market their products. The marketing organisations are separate registered concerns with their own boards of directors, on which, however, dye manufacturing interests have ample representation.

An important factor for the success of the Indian dyestuff industry will be the marketing of the products. Failure to compete with foreign concerns in the final stages of the industry, where marketing plays the greatest part, will lead to the decline of the industry in spite of the efficient conditions that may prevail in technical practice on the production side. Two alternatives may be considered. In one, a firm doing business in dyes at present by importing them may be given the responsibility for marketing the Indian dyes, dividing the country into several zones according to convenience. The second is to start a new marketing organisation consisting primarily of influential business men interested in the textile and millstore industries. If the Indian products are offered for sale by foreign organisations, we run the risk of being unknown in the market, since these firms may insist on marketing our products under their established trade names and marks, which are already well known. This would be inadvisable in the long run. Attempts should be made to market the products of the Indian factory under its own specific names, so that in due course the Indian products will be recognised and valued throughout the world in the same manner as the Indanthrenes, the Caledons, the Naphtols and the Brenthols.

State aid : What we have stated in the preceding chapters of this report has conclusively shown the imperative need of the fostering care of the state in the origin, growth and development of this industry. We have seen how, besides monetary assistance, the state in Great Britain and other countries found it necessary to prohibit the import of dyes competing with those of indigenous manufacture. Assistance by the state may take the form of participation in the capital of the industry. Also it may be found in the earlier stages of the development of the industry that the manufacture of some particular intermediates is necessary in the general interests of the country, as being essential to other industries besides dyes, even though such manufacture may not be financially profitable. In such a contingency the State should be ready to subsidise such manufacture until it is in a position to pay for itself. Further, the state should give an assurance that if

the industry requires assistance in the early stages against external competition, as it well may, the necessary amount of protection will be granted. Without such assurance, the position of the industry will become precarious and its progress will be seriously hampered. Few industries are so powerfully organised in competing countries as the dyestuff industry, and its establishment therefore in other countries that provide a large market for existing concerns is likely to meet with severe opposition. In these circumstances it is the obvious duty of the state to assure the industry that the necessary protection will be forthcoming.

Allied to this is the question of the excise policy. We have seen how an unsympathetic excise policy impeded the growth of the industry in Great Britain. In the preparation and purification of some of the dyes it is necessary to employ large quantities of pure alcohol. Government policy in this matter should not be such as to impair the development of the dye industry or of the allied fine chemical or pharmaceutical industries. The case of benzol is similar.

Railway freights : In a country of vast distances such as India, freights often constitute a very important factor of the cost of commodities. The dye manufacturer will have to move his raw materials to his factory over long distances and to deliver the finished product at widely distant centres. Special freight rates will, therefore, have to be granted, so that haulage costs may not constitute a heavy burden on the industry.

Patents : As we have seen, one of the causes of the weakness of the British dyestuff industry before the last war was the faulty patent laws then in existence. The British Patent Amendment Act of 1907 rectified the position. The Indian Patent laws should be so modified that the foreign patents dealing with dyes and intermediates taken out in India could be utilised by the Indian dyestuff industry on payment of fair and reasonable royalties.

Technical personnel and research : The question of the personnel to man the new industry is a very important one. In the early stages the assistance of experts and technicians from abroad will be required, but immediate steps must be taken to provide graduates of our Universities in Chemistry and Chemical Engineering with facilities for work on the chemistry and technology of dyes. A certain number of the more promising graduates should be sent to foreign countries for advanced training by arrangement with other dyestuff organisations through their respective Governments. A beginning has been made by the Council of Scientific and Industrial Research by subsidising the creation of a section of dyestuff technology in the Department of Chemical Technology of the University of Bombay.

The subject of technical research on synthetic dyes should be given an important place in the National Chemical Laboratory which is about to be founded. Research is the very life-blood of this industry. The predominance of Germany in this field is mainly due to its wonderful research organisation. The problem of research should be attacked on all fronts—in Government laboratories and university laboratories, as well as by the manufacturers themselves. It has been computed that the American dyestuff manufacturer spends five per cent. of his sale proceeds on research, devoted mainly to continuous improvement in methods of production and plant design. We would, therefore, urge that Government should set apart a substantial sum every year for research on the chemistry and technology of dyes to be dis-

bursed to the national laboratories as well as university laboratories, and that the dyestuff manufacturer should spend an equal sum on research after the industry has been properly established.

SUMMARY OF RECOMMENDATIONS

(1) In view of the vital importance of the dyestuff industry in the national economy, the industry should be established in India as early as possible.

(2) The plan for an Indian dyestuff industry should comprise

(*a*) the manufacture of the 51 dyes listed in Appendix I within a period of about five years after a brief period of preparation ;

(*b*) the manufacture of some of the intermediates during this 5-year period ;

(*c*) the production of all the intermediates required for the 51 dyes within 10 years ;

(*d*) the production of all the dyes in substantial demand in the country, together with all the necessary intermediates, within a period of 15-20 years.

(3) The products of the Indian dyestuff industry should be marketed in their own specific names, so that in course of time Indian dyes will be recognised and valued throughout the world.

(4) The wastage and uneconomic use of coal-tar and its products should be prevented by law. The specifications for road tar should be modified in order to ensure that the constituents valuable to the synthetic organic chemical industries are recovered as fully as possible.

(5) The dyestuff industry should if possible manufacture the following five important heavy chemicals, which are required in large quantities : sulphuric acid, hydrochloric acid, nitric acid, caustic soda and chlorine. In view of the inadequate resources of sulphur, gypsum must be employed as raw material for the production of sulphuric acid.

(6) Arrangements should be made with existing manufacturers of heavy chemicals for the supply of the other heavy chemicals required by the dyestuff industry ; but in the case of chemicals which are unobtainable at reasonable prices and in the requisite quantities, the dyestuff industry should itself undertake their production.

(7) A nitrogen fixation industry should be established as early as possible, under Government auspices if necessary. While the fixation of atmospheric nitrogen is necessary for the supply of nitrogenous fertilisers, the scale of production of synthetic ammonia should take into account the requirements of the dyestuff industry.

(8) Apart from the requirements of the dyestuff industry in this regard, production of synthetic methanol and formalin therefrom on a scale adequate for the purposes of the chemical industry in general, and an Indian plastics industry in particular, should be undertaken in India, under Government auspices if necessary.

(9) The manufacture of synthetic acetic acid and its derivatives on an adequate scale should be organised as early as possible.

(10) Immediate steps should be taken for the creation of a chemical engineering industry specialising in the fabrication of autoclaves, glass-lined and enamelled equipment and other plant required by the dyestuff and chemical industries. If such equipment cannot be manufactured in India in the immediate future, facilities should be provided for its importation from the United Kingdom and the United States of America.

(11) The location of the dyestuff industry should be decided by an expert committee after a survey of sites.

(12) The Indian dyestuff industry should come to an agreement for co-operation with a large and well established organisation in Europe or America, so that their technical assistance and expert advice would be available at every stage. Such co-operation should not be in any way at the expense of Indian interests and any company that may be formed should have a majority of Indian capital and Indian directors. As part of the agreement, arrangements should be made for the training of Indian technical personnel from the highest to the lowest, so that the industry may be entirely manned by Indian personnel within a reasonable period.

(13) The manufacture of intermediates and dyes should be carried out in one centralised factory manufacturing the whole series of dyes through all the stages, starting from the coal-tar raw materials.

(14) In providing for the organisation of an Indian dyestuff industry, every care should be taken that national interests are not sacrificed in favour of any external or group interests.

State aid in the following forms is recommended : (*a*) assurance of protection against external competition ; (*b*) financial participation or/and subsidies for the manufacture of intermediates required for the other chemical industries and which the dyestuff industry may not be able to produce economically ; (*c*) modification of excise policy, which will encourage the growth of the dyestuff, pharmaceutical and fine chemical industries ; (*d*) special freight rates for dyes and dye intermediates, so that haulage cost may not constitute a heavy burden on the industry ; (*e*) modification of Indian patent laws, so that patents taken out in India by foreign firms may be utilised by the Indian industry by payment of reasonable royalties ; (*f*) grants to be made to the National Chemical Laboratory and University Departments for training and research in the chemistry and technology of intermediates and dyes.

(15) Government should take early steps to institute an accurate survey of the production and consumption of inorganic chemicals, coal-tar distillation products and aliphatic chemicals in the country.

(16) The Department of Commercial Intelligence and Statistics should indicate in the published trade returns the import figures relating to each important individual dye.

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